Combining Differential and Integral Cross Sections to Improve Nuclear Data for Fission Applications

Toshihiko Kawano (T-16), Kenneth M. Hanson (CCS-2/T-16), Stephanie C. Frankle (X-5), Patrick Talou and Mark B. Chadwick (T-16), and Robert C. Little (X-5)

Since high accuracy is required for fission cross sections of uranium and plutonium isotopes in neutron transport calculations, improvement of fission cross-section data in the evaluated nuclear data libraries has very high priority in a nuclear data study. The fission cross-section data (differential data, as a function of neutron energies) have been measured in various laboratories in the past. However, we still see discrepancies among different experimental data sets, which leads to an inaccurate prediction of neutron multiplication.

The critical assembly experiments at Los Alamos National Laboratory (LANL) such as Godiva and Jezebel, which are relatively simple, well characterized, and highly accurate, have been used for data testing and validation. We have utilized those integral measurements to constrain the differential fission cross sections by using a Bayesian technique. With this method, we can reduce uncertainties in the fission cross sections, and the combined differential/integral data can predict the neutron multiplication within the accuracy of LANL critical assembly experiments, which are typically less than 0.5%.

The fission cross section of Pu-239 was evaluated based on the differential experimental data, and those uncertainties (variance/covariance) were estimated from those experiments, which are shown by the red line in Fig. 1 (variance) and Fig. 2 (correlation matrix). We performed the neutron transport calculations for Jezebel, and sensitivity coefficients of cross sections to the neutron multiplicity were obtained. Then the fission cross sections were adjusted to the Jezebel experiment with the Bayesian method. The combined uncertainties are shown in Fig. 1 by the blue line. The change in the fission cross sections are usually very small. However, the uncertainties become smaller and negative correlations appear as shown in Fig. 3.

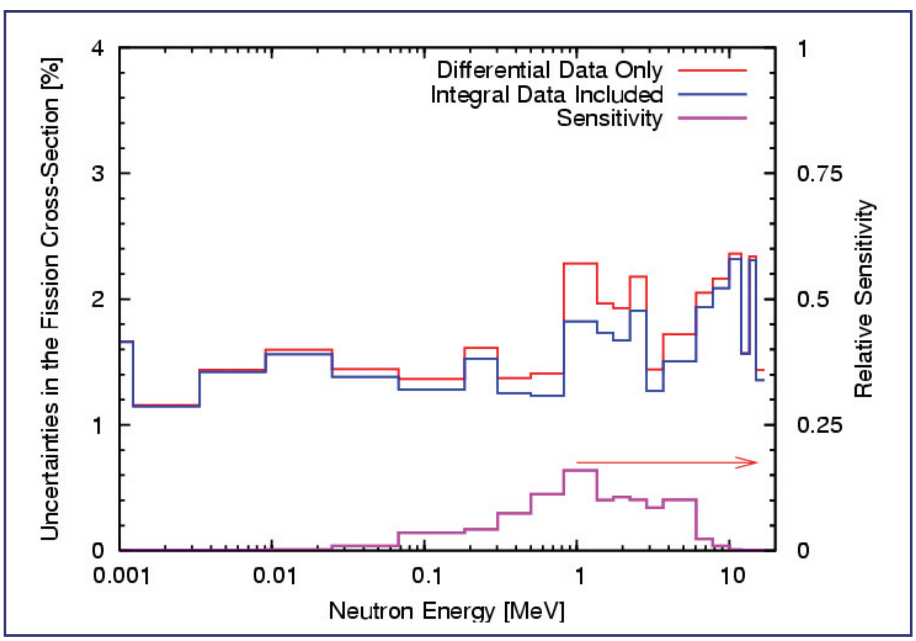

***Figure 1—* Estimated uncertainties in the Pu-239 fission cross sections.**

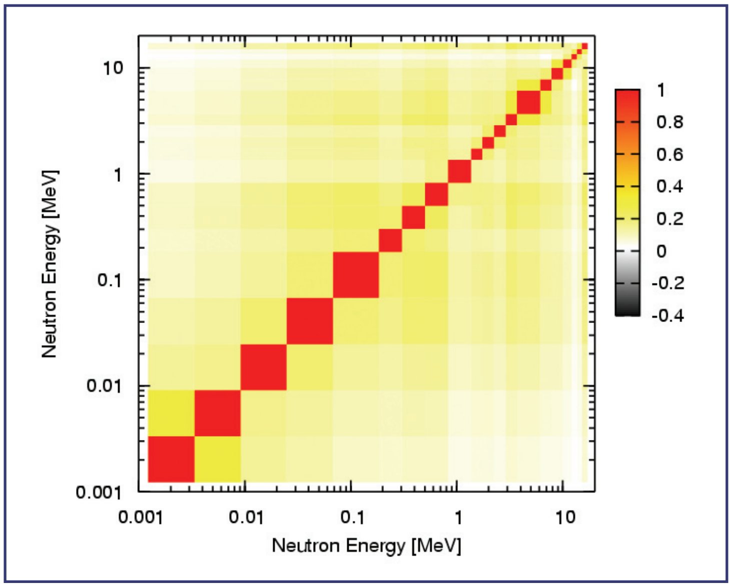

Figure 2—
Correlation matrix for the Pu-239 fission cross sections. The differential data are only included.

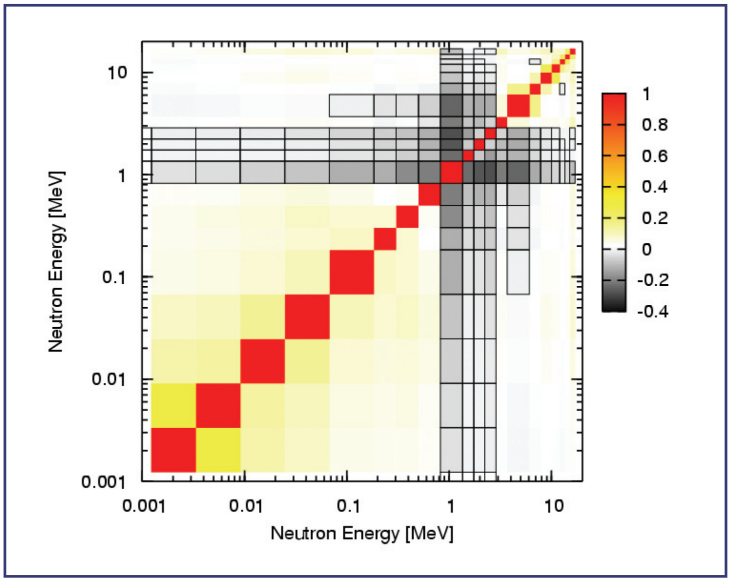

Figure 3—
Correlation matrix for the Pu-239 fission cross sections. The integral data are combined with the differential data.

These negative correlations constrain the fission cross sections to keep the integral quantities constant. If we generate randomly sampled fission cross section ensembles in accordance with this covariance, the calculated neutron multiplicities for Jezebel form a Gaussian distribution of 0.2% uncertainty.

For more information, contact Toshihiko Kawano (kawano@lanl.gov).

Acknowledgements
We would like to acknowledge NNSA's Advanced Simulation and Computing (ASC), Verification and Validation Program for financial support.

Los Alamos
NATIONAL LABORATORY
EST. 1943